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8000-Year old rice remains from the north edge of the Shandong Highlands, East China

GuiYun Jin [a,*], WenWan Wu [a], KeSi Zhang [b], ZeBing Wang [b], XiaoHong Wu [c,**]

[a] Center for East Asia Archaeology Research, Shandong University, Jinan 250100, China
[b] Shandong Provincial Institute of Cultural Relics and Archaeology, Jinan 250014, China
[c] School of Archaeology and Museology, Peking University, Beijing 100871, China

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ABSTRACT

Systematic archaeobotanical work at Xihe site recovered 8000 years old rice and other plant remains. Cultural context analyses of the plant and animal remains indicated Xihe people relied mainly on fishing–hunting–gathering as their subsistence. As the largest amount and higher concentration of plant remains, rice might contribute much to plant food resource at the settlement. Even though it is too early to demonstrate the nature of the rice remains (whether it is wild, cultivated or domesticated), the case that discovery of Xihe rice has undoubtedly provided new evidence for our understanding of rice exploitation subsistence at about 8000 years ago in East China.

1. Introduction

As a staple food, rice plays a very important role in modern life all over the world. Archaeologists, biologists, climatologists, and other scientists are interested in the origin and early development of rice agriculture. However, the origins of rice cultivation and domestication are currently hotly debated among scholars (e.g. Fuller et al., 2007; Liu et al., 2007; Zhao, 2011). The issues involve a number of distinct topics like where, when, how and under what circumstance did cultivation or domestication happen. Furthermore, the new discoveries of rice remains at Yuezhuang (ca. 8000 cal BP) (Crawford et al., 2006) in the northern edge of the Shandong Highlands make the above debate much more complicated as the site is far from the origin areas of rice agriculture that have been traditionally suggested (Fuller et al.,, 2007; Liu et al., 2007). Some people believe that the rice remains recovered at Yuezhuang were cultivated or even domesticated (Zhao, 2011); while others suggest that the nature of these rice remains was unclear (Fuller and Qin, 2009; Fuller et al., 2009). Some scientists take the findings as an "unexpected" early arrival of rice in the Yellow River area (Bar-Yosef, 2011). It is doubtless that the nature of the rice remains from Yuezhuang not only make the understanding of rice exploitation or cultivation more complicated but also is very important for the study of rice agriculture in East China. For this reason, it is necessary to examine more archaeological evidence, including plant remains from more sites, which are archaeologically similar to Yuezhuang in order to understand the significance of these rice remains. The systematic archaeobotanical work undertaken during the salvage excavations of Xihe provides us with this opportunity. The aims of this paper are to (1) present the results of the intensive archaeobotanical work at Xihe; (2) further understand the status of the rice remains of the Houli Culture by thoroughly analyzing their cultural contexts and implications for the study of Neolithic rice exploitation; (3) discuss the subsistence pattern of the Houli Culture and its significance for research on the early food production in East China.

2. Natural environment and archaeological findings at Xihe

Xihe is situated about 500 m northwest of Longshancun near the town of Longshan in Zhangqiu Municipality, Shandong Province. The western part of the site projects out towards the Xihe River, which surrounds the northern, southern and western sides of the site, and hence the site was named after the river (Fig. 1(a)).

Xihe site is situated in the flatlands bordering the northern foothills of the Tai-Yi Mountain Range, at an altitude of about 50 m a.s.l. (Shandong Provincial Local History Compiling Committee, 1996, 62, 117). The variation of topography led to the complexity

* Corresponding author. Tel.: +86 531 88366056; fax: +86 531 88362663.
** Corresponding author. Tel.: +86 10 62755264; fax: +86 10 62757493.
E-mail addresses: gyjin@sdu.edu.cn (G. Jin), wuxh@pku.edu.cn (X. Wu).

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of the environmental diversity which was important for early Neolithic residents. The average annual temperature amounts to 14–15 °C and annual average precipitation is around 700–800 mm (Shandong Provincial Local History Compiling Committee, 1996, 129–166). The deep soil (loess sediments of 50–80 m deep) and abundant water sources from mountain springs in the south are especially ideal for farming which led to the deforestation and characteristic man-made vegetation of crops dominated by wheat and corn (Shandong Provincial Local History compiling committee, 1996, 264–266, 362, 412). Very small scale rice agriculture developed in some special areas about 20 km away from Xihe.

In 1991, 1997 and 2008, a total of 2870 m^2 of the site was excavated by salvage excavation projects (Shandong Provincial Institute, 1993, 2000; Wang et al., 2012). About 38 houses were found, which were arranged in an orderly fashion and roughly clustered together (see Inline Supplementary Fig. S1). The pattern indicated that at that time settlers were used to systematically planning the layout of a settlement. The living space of the houses is clearly divided into three zones (see Inline Supplementary Fig. S2), namely the cooking zone, the working and storage zone and the sleeping zone. Ceramics like pots, jars, bowls, bottles and stands, stone tools such as axes, adzes, hammers, millstones and pestles, and a small amount of bone implements were found on the floors (see Inline Supplementary Fig. S3). 20 storage pits have been found which were situated either between or inside the houses. The infills of most pits consist mainly of lumps of loess and the remains of daily lives, such as broken bones from one pit (H358).

Inline Supplementary Figs. S1–S3 can be found online at http://dx.doi.org/10.1016/j.jas.2013.01.007.

A cluster of sites with similar cultural contexts such as Xihe and Yuezhuang are located along the northern edge of the Shandong Highlands (Fig. 1(b)) and they belonged to the Houli Culture, so named after the excavation at the Houli site in Linzi, Zibo Municipality, Shandong Province (Wang et al., 1993). Being the earliest Neolithic culture on the edge of the Shandong Highlands, East China, known so far, the Houli Culture marks the starting of point of the Neolithic way-of-life in this region (Luan, 2009). Nonetheless, it is necessary to obtain more evidence regarding the subsistence transition from foraging to food producing modes by examining more individual site like Xihe and Yuezhuang (Crawford et al., 2006).

3. Materials and methods

During the excavation in 2008, soil samples for both flotation and phytolith analyses were collected from *in situ* archaeological contexts, such as house floors and ash pits. For flotation, sample sizes varied with feature sizes, but 10 L was the target volume. A froth-flotation device with a 0.2-mm mesh screen for light fraction samples and 1.00 mm for heavy fraction was used. The phytoliths were extracted using normal procedures (Pearsall, 1989) and both the carbonized plant remains and phytoliths were identified and photographed at the Archaeobotanic Lab in Shandong University with a Nikon SMZ 1000 and Nikon E800, respectively. The nomenclature follows Floral China (Editorial Committee of Flora Reipublicae Popularis Sinicae, 2001). Seeds were studied under a dissecting stereomicroscope (Nikon SMZ645). Seed size, external features and internal anatomy were used for identification by comparison with modern plant specimens from the archaeobotanic

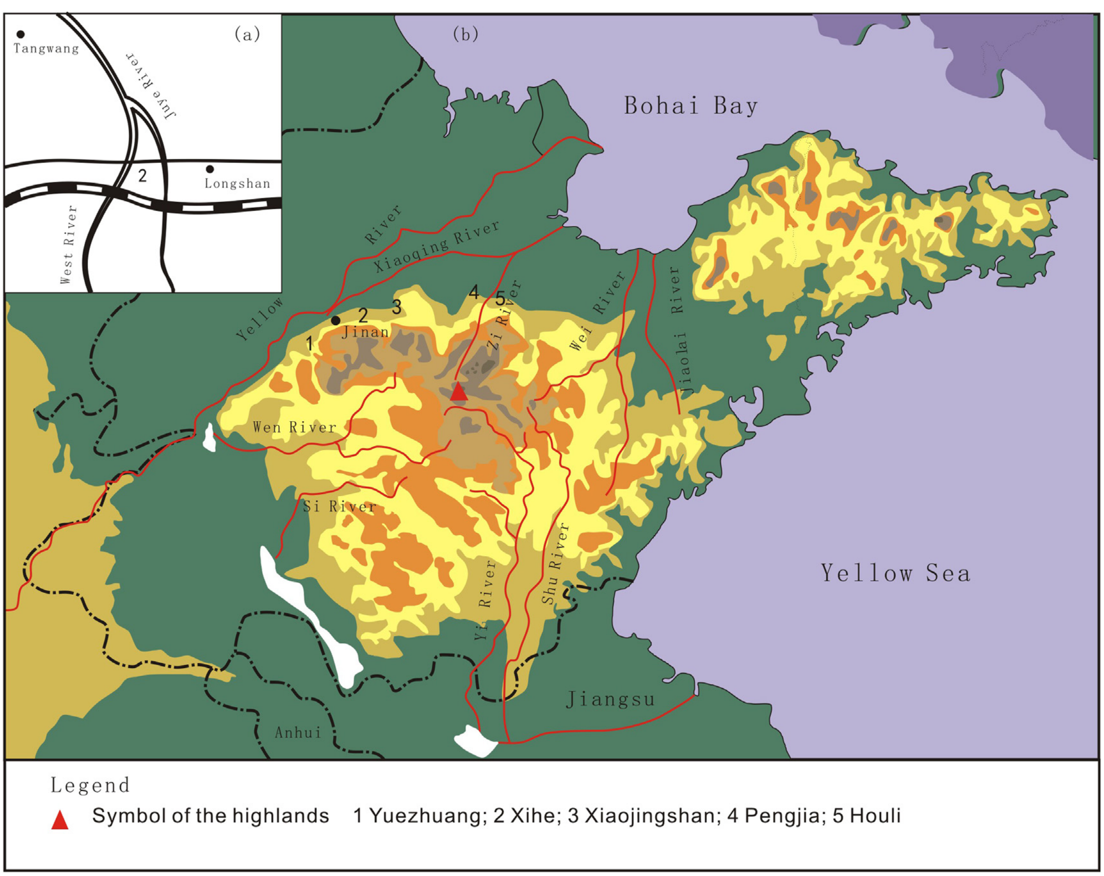

Fig. 1. (a) Location of Xihe; (b) distribution of mainly Houli Culture sites.

laboratory in Shandong University and published identification keys (Liu et al., 2008). Phytoliths were studied under a transect stereomicroscope (Nikon E800). Shape and texture of the surface of the phytoliths were used for identification by comparison with modern rice and millet phytoliths from the same lab for seeds and fruits identification and published identification keys (Fujiwara, 1993; Zhao et al., 1998; Lu et al., 2009; Zhang et al., 2011). For the interpretation of the results, the remains were quantified, not taking the fragments and the remains without precise identification into account. All those identified seeds or fruits, either intact or broken, were counted as an individual when the area of the embryo was preserved, excluding the fragments without this feature. Another index used is ubiquity, which is the number of samples or structures in which plant remains of a given taxon that was expressed as percentages are identified.

The chronology of the settlement was constructed on 11 AMS radiocarbon dates which came from charred plant remains (seeds, fruits and charcoal) (Table 1). Dating was performed at the Radiocarbon Laboratory of Scientific Archaeology & Cultural Relics Preservation of Peking University and 14C dates were calibrated using OxCal v3.10. The half year is 5568 and BP means from 1950.

4. Results

4.1. Chronology

The dates (Table 1) from three samples of a stack of charcoal or stems are relatively late, especially the sample of F303①. It is suggested that these samples might be contaminated by late material. The other 8 dates of seeds or fruits fell within the range of 6070–5900 cal BC.

4.2. Carbonized seeds

202 seeds from the site were positively identified as 18 types of plants and could be further assigned to their species, genus or family (Table 2). The remaining plant remains were recorded as unknown seed types, whose preservation level were poor or the fragment was unidentifiable.

All rice grains represent a similar form to *Oryza* sp. (Fig. 2(a–c)). Foxtail millet grains are morphologically different from the wild grasses and exhibit the distinctive characteristics of domesticated species which are more spherical in shape and large in size

Table 1
Dates of Xihe site from the excavation in 2008.

Lab no.	Sample (charred seeds)	Feature	14C date (BP)	Calibrated date (Cal BP)	
				1σ (68.2%)	2σ (95.4%)
BA10679	Rice 1	H358③	7090 ± 30	7960 (40.4%) 7925 7900 (27.8%) 7870	7980 (95.4%) 7850
BA10680	Rice 1	H358②	7115 ± 30	7975 (62.3%) 7930 7890 (5.9%) 7880	8010 (78.1%) 7920 7900 (17.3%) 7860
BA10681	Rice 1	H358②	7165 ± 30	8005 (68.2%) 7960	8025 (95.4%) 7940
BA10682	Rice 1	H358③	7165 ± 25	8005 (68.2%) 7960	8020 (95.4%) 7945
BA10683	Grape 1	F305①	7085 ± 30	7960 (36.1%) 7925 7900 (32.1%) 7870	7970 (95.4%) 7840
BA10684	A pack of stems	F306②	6765 ± 30	7660 (20.3%) 7635 7625 (47.9%) 7985	7670 (95.4%) 7575
BA10686	Grape 1	F305②	7120 ± 30	7975 (67.1%) 7930 7890 (1.1%) 7880	8010 (82.3%) 7920 7900 (13.1%) 7870
BA10687	Papaveraceae 6 (Poppy family)	F307①	7125 ± 30	7980 (68.2%) 7930	8010 (85.5%) 7920 7900 (9.9%) 7870
BA10689	A pack of charcoal	H337	4650 ± 25	5450 (60.6%) 5380 5330 (7.6%) 5310	5470 (95.4%) 5310
BA10690	Fragmented nuts 3	F308③	7120 ± 30	7975 (67.1%) 7930 7890 (1.1%) 7880	8010 (82.3%) 7920 7900 (13.1%) 7870
BA10691	A pack of charcoal	F303①	735 ± 25	690 (68.2%) 665	725 (95.4%) 655

Table 2
Carbonized seeds recovered from Xihe site.

Items	Units										
	F303①	F305①	F305②	F306①	F306②	F307①	F308③	H337	H358②	H358③	Total
Volume of soil (L)	9	14	7	8	13	9	9	7	25	94	188
Oryza sp. L.		1							24	49	74
Setaria italica Beauv.						1				1	2
Fabaceae				1						3	4
Poaceae	1					1		1	3	5	11
Setaria sp.							1				1
Echinochloa Beauv.									3	9	12
Eleusine indica (L.) Gaertn.										4	4
Cyperus sp.						1					1
Carex sp.										1	1
Scirpus sp.					1						1
Chenopodium sp.	1	4		1	1	1	2		9	24	43
Amaranthus sp.				1		1	1				3
Asteraceae						1				4	5
Hibiscus trionum L.		1			1	23	1		2	1	29
Papaveraceae						6					
Vitis sp.		1	1			1					3
Morus sp.	1										1
Prunus davidiana Franch.									1		1
Total	3	7	1	3	3	36	5	1	42	99	202

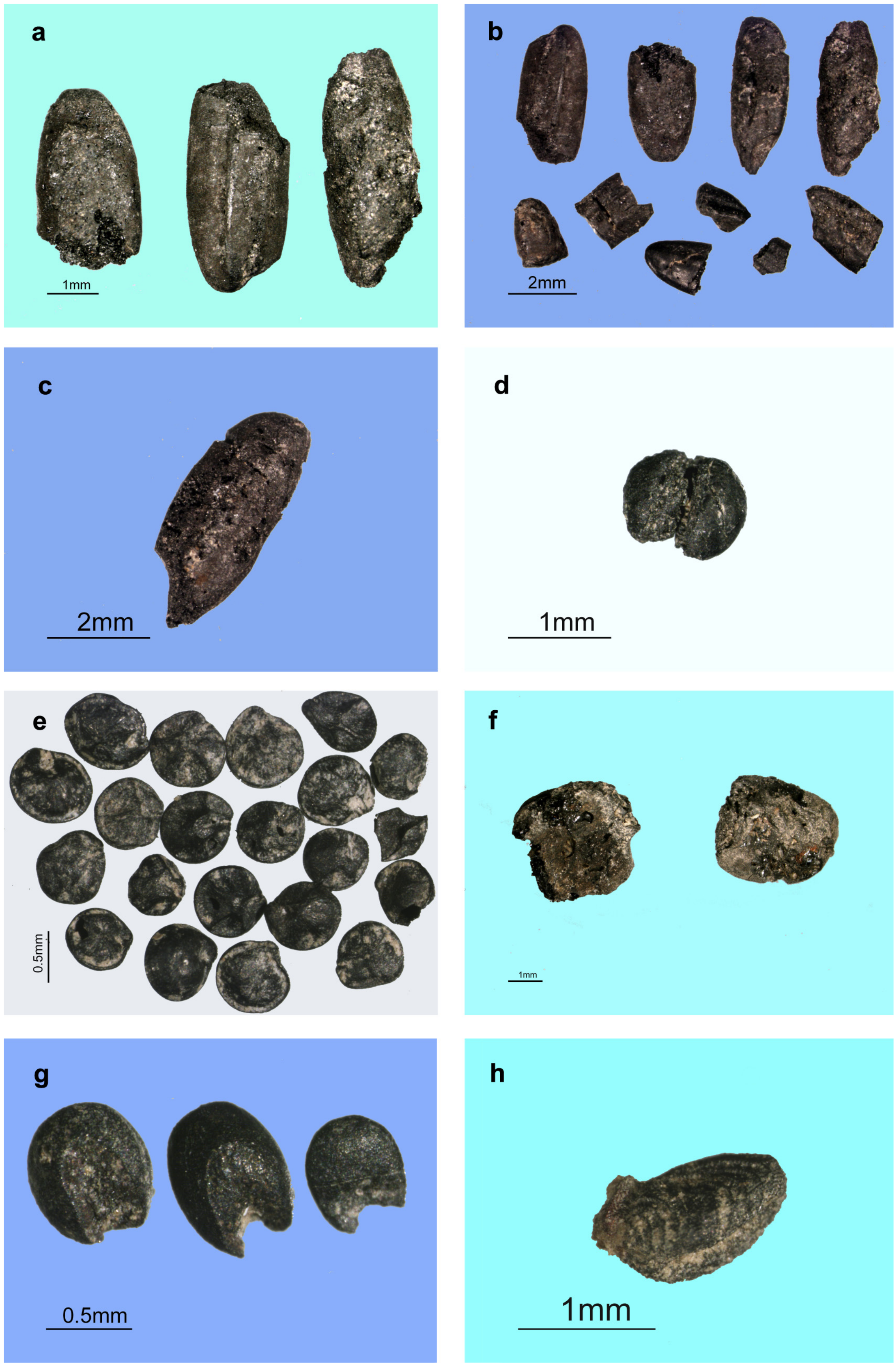

Fig. 2. Charred plant remains from Xihe site. (a)–(c) *Oryza* sp.; (d) *Setaria italic* L.; (e) *Chenopodium* sp.; (f) Fabaceae; (g) Poaceae; (h) *Eleusine indica* (L.) Gaertn.; (i) *Carex* sp.; (j) *Vitis* sp.; (k) *Cyperus* sp.; (l) *Hibiscus trionum* L.

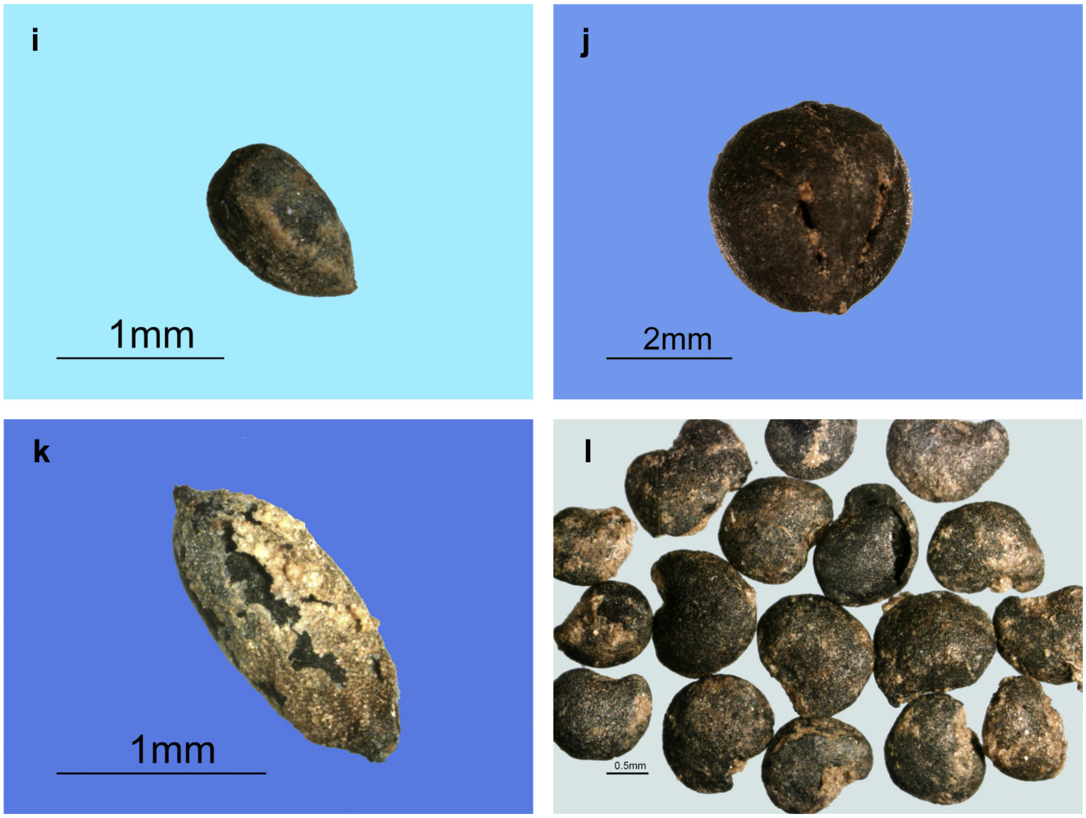

Fig. 2. (*continued*).

(Fig. 2(d)). *Chenopodium* can be confirmed to *Chenopodium album* according to the smooth testa and its relatively large size (Fig. 2(e)). Other charred seeds with better preservation are identified as Fabaceae (Fig. 2(f)), Poaceae (Fig. 2(g)), *Eleusine indica* (L.) Gaertn. (Fig. 2(h)), *Cyperus* sp. (Fig. 2(i)), *Carex* sp. (Fig. 2(j)), *Hibiscus trionum* L. (Fig. 2(k)), *Vitis* sp. (Fig. 2(l)), *Setaria* sp., *Echinochloa* Beauv., *Amaranthus* sp., Asteraceae, *Scirpus* sp., Papaveraceae, *Morus* sp. and *Prunus davidiana* Franch.

694.5 L of soil from 101 samples were floated. 202 identified carbonized seeds were recovered from only 195 L of soil from 24 samples (belonging to 10 archaeological units). Among 202 seeds, 60 (1 rice grains) are from 7 samples of house floor and 142 from 3 samples of pit. Among the 142 seeds from pit samples, 141, including 74 rice remains, came from pit H358. It is obvious seeds, especially rice remains, were concentrated in pit H358.

18 types of plants have been recovered from Xihe. Among these plants, the most abundant is rice; *Chenopodium* has the highest ubiquity; *H. trionum* L. is the third in terms of its amount and frequency (Fig. 3). Poaceae were regularly present in considerably lower numbers but in fairly high frequency.

74 rice grains (the fragments which can be identified unmistakably as rice are counted here) have been identified. Among these grains, 38 were preserved more than half of the grain and available for width and thickness measurement, 22 were complete for length measurement, and the other 36 fragments are smaller than half size but can be identified as rice. The average width is 1.72 mm with the widest at 2.29 mm and narrowest 1.02 mm, the average length is 3.77 mm with the longest at 5.29 mm and shortest at 2.9 mm. The length to width ratio (2.19) is close to that from Kuahuqiao (Zhejiang Provincial Institute of Cultural Relics and Archaeology, 2004, 273–277) and the first stage of Jiahu (Henan Provincial Institute of Cultural Relics and Archaeology, 1999, 887); but the average thickness (1.2 mm) seems much smaller than the populations from Kuahuqiao (1.9 mm) (Fuller et al., 2010). No spikelet bases are present to indicate non-shattering.

4.3. Phytolith data

Soil samples from 19 archaeological units have been used to extract phytolith (Table 3), and phytoliths were recovered from 3 samples. The identification shows that (1) abundant phytoliths were recovered from soil samples of pit H358 and (2) among these phytoliths, the most abundant is bar-shaped which is unclear of origins, the second one is peak-shaped which originates from rice (*Oryza* sp.) husk. Very few were identified as fan-shaped from rice leaf (Fig. 4). All the other phytoliths, including a few ones from pit H358 which are originated from the husk of millets and some fan-shaped from other archaeological units which are originated from reed, are poorly preserved.

5. Discussions

Although Xihe is not rich in archaeobotanical remains, it has been relatively systematically sampled and studied. The data are representative of the plant exploitation at the settlement and, accompanied with archaeological and archaeozoological data, should contribute to our understanding of the subsistence of the Xihe site or even the Houli Culture.

5.1. Fishing–hunting–gathering subsistence at Xihe

Archaeobotanical and archaeozoological evidence suggest that the subsistence of the Xihe site was characterized mainly by fishing–hunting–gathering.

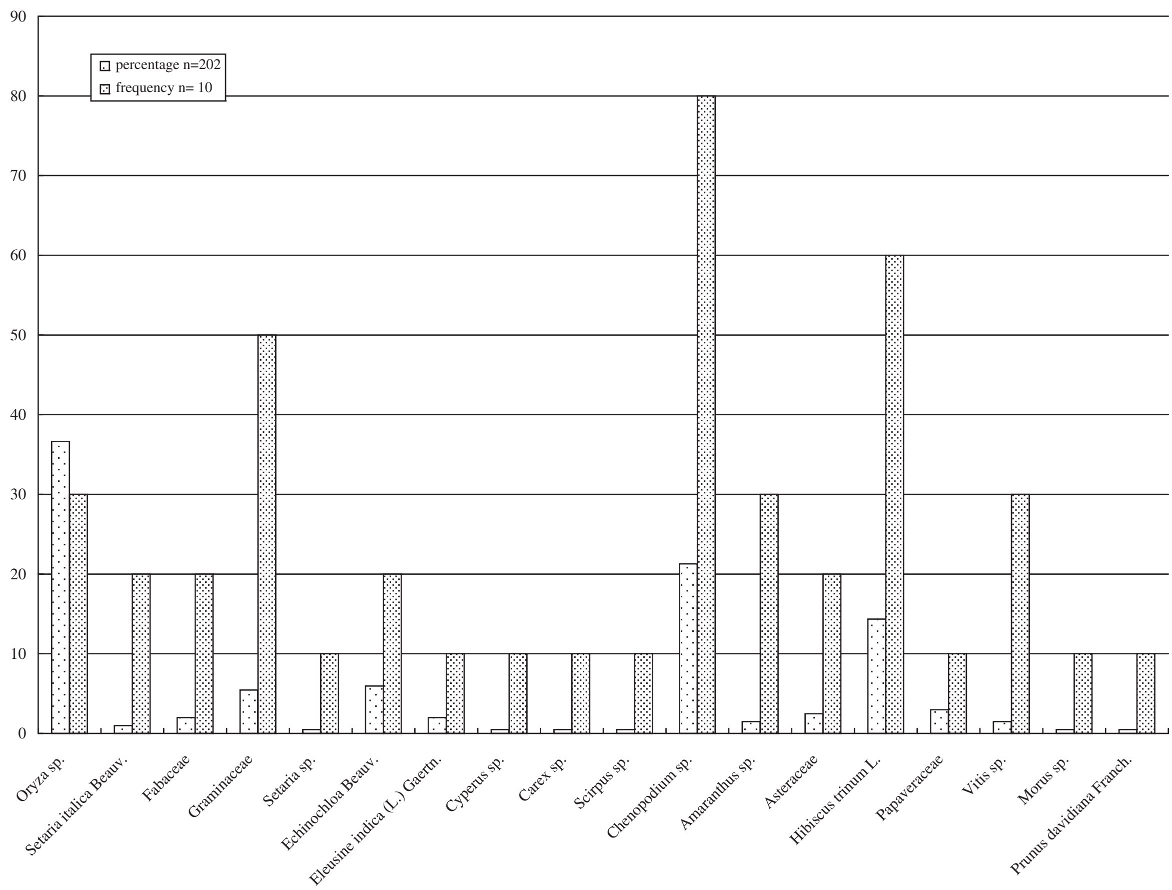

Fig. 3. Seeds percentage and frequency at Xihe.

The flotation results indicate that plants should be an important component of the food resources at the Xihe site. According to Chinese economic plant records, *C. album* (fat hen) and *H. trionum* recovered from Xihe might have been purposefully collected for human use. Two species of *Chenopodium* sp. are common economic plants in Shandong which grow on the fields, roadside, fallow field, or the periphery of settlements. In other words, they can be gathered easily. The whole plant can be used as medicine, and young individuals can be used as greens (Shandong Provincial Economic Plants Editing Committee, 1978, 81–82). There is no doubt that *Chenopodium* has been gathered for a long time. In Chinese archaeological sites, *Chenopodium* were recovered from Xinglonggou (Zhao, 2011) and other Neolithic sites like Liuzhuang (Wang et al., 2010). In Europe, more and more archaeobotanical evidence indicates the human assumption of the seeds of this plant (Behre, 2008). *H. trionum* L. is an annual herb, of which the plant

Table 3
Phytolith of Xihe site from the excavation in 2008.

Sample no.	Bar-shape	Peak-shape originated from rice	Fan-shape originated from rice	Fan-shape originated from reed	Phytolith originated from foxtail millet husk	Phytolith originated from broomcorn millet husk
F301	0	0	0	0	0	0
F302	0	0	0	0	0	0
F303	0	0	0	0	0	0
F304	0	0	0	1	0	0
F305	0	0	0	0	0	0
F306	0	0	0	0	0	0
F307	0	0	0	0	0	0
F308	0	0	0	0	0	0
H122②	0	0	0	2	0	0
H122③	0	0	0	0	0	0
H123②	0	0	0	0	0	0
H337	0	0	0	1	0	0
H343	0	0	0	0	0	0
H344	0	0	0	0	0	0
H345	0	0	0	0	0	0
H346	0	0	0	0	0	0
H358②	220	148	4	0	2	1
H358③	260	136	5	0	1	1
H360	0	0	0	0	0	0

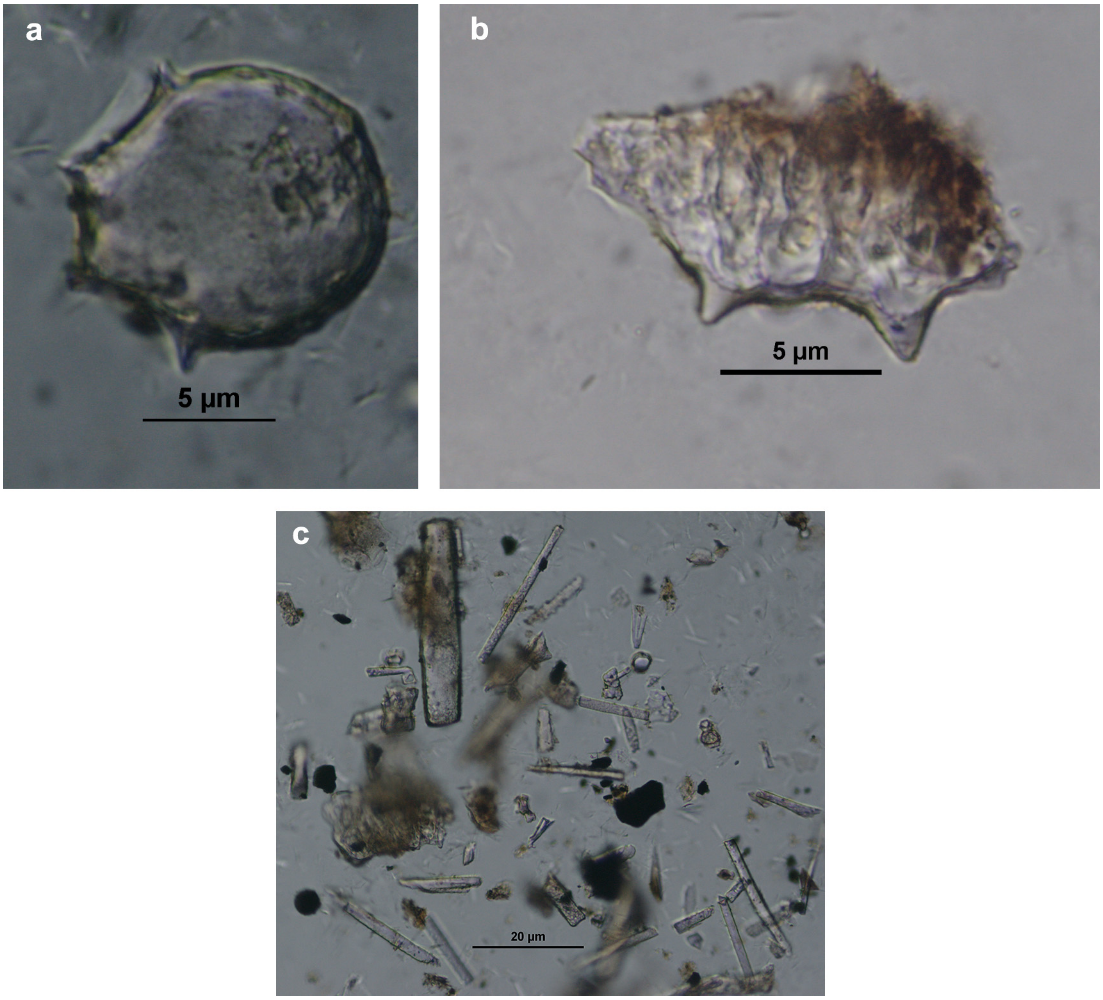

Fig. 4. Phytolith from soil samples of H358. (a) Fan-shaped; (b) peak-shaped; (c) bar-shaped.

and seeds can be used as medicine (Hygiene Section of the Rear Service Department of Shenyang Troops, 1970, 302–303). Its concentration on house floors (F307 which is also the feature with the third numerous wild plants remains) and its relative high ubiquity imply the probability of human consumption at Xihe. At the Zhaojiazhuang site, which is dated to 4300 cal BP on the eastern edge of the Shandong Highlands, some charred *H. trionum* L. seeds were recovered from pits (Jin et al., 2011). Fabaceae, *Vitis* sp., *Morus* sp. and *P. davidiana* Franch., which are all food resources for the Neolithic people, are present in low numbers and ubiquities. Hence, it is difficult to confirm their significance.

Archaeozoological remains from Xihe indicate the large consumption of animal resources (Song, 2012). 9297 pieces of animal bones were recovered from Xihe site and 5197 pieces have been identified as cattle (*Bos* sp.), deer (*Cerves* sp.), pig (*Sus* sp.), dog (*Canis familiaris* L.), clam (*Lamprotula* sp.), spiral shell belonging to the family of Gastropoda, carp (*Cyprinus* sp.), grass carp (*Ctenopharyngodon* sp.), turtle (*Amyda* sp.), bird, bamboo rat (Rhizomyidae), small carnivore belonging to the family of Carnivora, and rodents. Pig might have been domesticated, while other animals were all wild. Among the assemblages of animal remains, 59% are fresh-water fish bones; 19% are bird bones; 18% are mammal bones; 4% are mollusca. Reptiles are present rarely in the assemblages. Large quantities of animal remains were recovered not only from Xihe but also from other Houli Cultural sites like Xiaojingshan (Kong, 1996) and Pengjia (communication with the excavator M.K. Gao, 2006). Stable isotope studies of human bone from Xiaojingshan indicate C4 plants (millets) contribute only 25% of dietary protein in 8000 cal BP (Hu et al., 2008).

Rice remains are the largest quantity and most highly concentrated of the plant remains at Xihe. It is very interesting to understand their implications as their presence at Xihe and Yuezhuang provides very important evidence for the Neolithic use of the rice genus in East Asia.

5.2. The implications of Xihe rice

The presence of rice remains at Xihe site is not only extraordinarily far beyond the traditionally known area of rice agriculture origin (Fuller et al., 2007), but also raise more questions about the subsistence of the Houli Culture instead of providing some definite answers. Thus, the discovery has contributed to our understanding of the Neolithic rice exploitation in China.

5.2.1. Was Xihe rice wild?

The present evidence indicates two major issues. First, the presence of wild rice inside or surrounding Xihe, implies more work is needed to reconstruct the regional or local vegetation during the Holocene. Second, it is difficult to determine whether the Xihe rice was wild or domesticated based on present data.

Biological investigations showed modern wild rice populations were not distributed beyond the Yangtze River Valley (Pang and

Chen, 2002). Considering the warmer and wetter conditions in the early Holocene, the pattern of wild rice distribution should be different from the present and it would seem likely that there were wild rice populations on the north edge of the Shandong Highlands (Fuller et al., 2010). However, there has been no vegetational evidence forthcoming to prove this assumption. There have been some general publications about regional climate or vegetation changes during the Holocene (Chen and Wang, 2012), but no of these results provide any information on the vegetation during the Houli Culture.

Wild grown rice was indeed once recorded in the Shandong area in historical documents of the Song Dynasty (You, 1987). However, we should not take these records uncritically before any other verification or evidence is available. It is generally accepted that many aspects recorded in Chinese historical documents need to be verified by textual criticism or other kinds of evidence like excavated data because the contradictions between texts and archaeological evidence (Falkenhausen, 2006).

Although Xihe rice might have been domesticated according to their archaeological contexts (Zhang, 2011), on the basis of their morphological characteristics, it is difficult to discuss the nature of whether those were wild or domesticated because no spikelet is present to indicate the nature of non-shattering rachis which is the best and least ambiguous trait of domestication. Also, it is obvious that Xihe rice is smaller than that from Kuahuqiao which is considered as pre-domesticated rice (Fuller et al., 2010) (see Inline Supplementary Fig. S4).

Inline Supplementary Fig. S4 can be found online at http://dx.doi.org/10.1016/j.jas.2013.01.007.

5.2.2. *Was Xihe rice cultivated?*

The absence of morphological traits of domestication does not rule out the possibility of pre-domestication cultivation. Identification of several species of weeds, which are normally suggested as field ones, indicates that the Xihe rice may have been cultivated. Nonetheless, in order to demonstrate the presence of rice cultivation, more research on the settlement pattern and probable rice fields must be carried out at Xihe or other Houli Culture sites.

The presence of seeds of *Echinochloa* Beauv., *Cyperus* sp., *Carex* sp, *Scirpus* sp. at Xihe might indicate weeds were grown in cultivated fields or gathered at the settlement. In Europe, cultivation was also identified in many cases by arable weeds in cereal caches (Bogaard et al., 1999; Harris, 2007). Although two foxtail millet grains from Xihe are too few to discuss their implications for plant exploitation, considering the domesticated morphological characteristics of these two grains and 40 broomcorn and 1 foxtail seeds (together with 26 rice grains) from Yuezhuang (Crawford et al., 2006), we suggest the millet cultivation might have developed at Xihe. Archaeobotanical data from the Xinglonggou (Zhao, 2011) and Cishan (Zhao, 2011) sites (see Inline Supplementary Fig. S4) also suggest that millets cultivation may have been developed during the time range of the Houli Culture.

Nevertheless, in order to demonstrate the presence of rice cultivation at Xihe or in the Houli Culture, the most direct evidence of rice field must be investigated and the settlement pattern as a complimentary evidence should be studied. It is crucial for the understand of cultivation to establish whether the Xihe people were settled year-round or were seasonally mobile. Furthermore, several questions closely related with rice cultivation must be answered. If the Xihe rice was cultivated, these questions include: (1) did the rice cultivation develop from early regional wild rice collecting or was it introduced by migrants from other areas as suggested by scholars (e.g. Zhang, 2011)? (2) where did the migrants come from if it was brought from outside?

6. Conclusions

In summary, archaeological data from Xihe and other Houli Culture sites like Yuezhuang indicated that fishing-hunting-gathering was the main subsistence but raise important questions about the nature of Xihe rice which are essential for our understanding of Neolithic rice exploitation and its environmental background in East China.

In spite of the uncertainties of the nature of Xihe rice, it is undoubtedly the case that rice was an important plant resource in Xihe subsistence.

Archeological contexts show rice was valued as one type of important stable food by Xihe residents. During the excavation in 2008, 11 pits were excavated but only one pit (H358) located within a house floor, indicating its special significance for the settlement. Archaeobotanical (carbonized plant remains and phytolith) data also show its importance by the high concentration of rice and other plant and animal remains (more than 90% animal bones come from H358 and among these are 60% fish remains). It is believed that Xihe rice did not appear to have been an everyday food resource but must have been one of the most important plant food resources for the villagers. The archaeobotanical data from Yuezhuang (Crawford et al., 2006) and Xinglongwa (Zhao, 2011) also show the high concentration of rice and millets remains in these settlements.

The documentation of Xihe rice (also Yuezhuang) establishes a key reference point for the early rice exploitation in China. It is obvious that, at Xihe settlement, rice was an important food stuff but that residents based their subsistence mainly on fishing–hunting–gathering, which was the common subsistence strategy adopted by the contemporary residents at Xinglonggou, Jiahu (the first stage), Bashidang and Kuahuqiao (Fuller et al., 2007). Lastly, as it is the beginning of the research on the Houli Culture subsistence, the present study on the archaeobotanical (including some archaeozoological) evidence from Xihe and Yuezhuang perhaps raises more questions than answers.

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Appendix A. Supplementary material

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.jas.2013.01.007.

References

Bar-Yosef, O., 2011. Climatic fluctuations and early farming in West and East Asia. Current Anthropology 52 (S4), S175–S193.

Behre, K.-E., 2008. Collected seeds and fruits from herbs as prehistoric food. Vegetation History Archaeobotany 17, 65–73.

Bogaard, A.C., Palmer, G.J., Charles, M., 1999. A FIBS approach to the use of weed ecology for the archaeobotanical recognition of crop rotation regimes. Journal of Archaeological Science 26, 1211–1224.

Chen, W., Wang, W.M., 2012. Middle-late Holocene vegetation history and environment changes revealed by pollen analysis of a core at Qingdao of Shandong Province, East China. Quaternary International 254, 68–72.

Crawford, G., Chen, X., Wang, J., 2006. Carbonized rice remains from the Yuezhuang site, Changqing County, Jinan Municipality, Shandong (in Chinese, with English abstract). In: Center for East Asia Archaeology Research of Shandong University (Ed.), Oriental Archaeology (3). Science Press, Beijing, pp. 247–251.

Editorial Committee of Flora Reipublicae Popularis Sinicae (Wu Zhengyi (吴征镒) and Peter H. Raven as Co-Chairs of the Editorial Committee), 2001. Flora of China: Illustrations. Science Press/Missouri Botanical Garden Press, Beijing/St. Louis.

Falkenhausen, Lothar von, 2006. Chinese Society in the Age of Confucius (1000–250 BC): the Archaeological Evidence. Cotsen Institute of Archaeology, University of California, Los Angeles, pp. 1–27.

Fujiwara, H., 1993. Research into the history of rice cultivation using plant opal analysis. In: Pearsall, D., Piperno, D. (Eds.), Current Research in Phytolith Analysis: Application in Archaeology and Paleoecology. University of Pennsylvania, Philadelphia, pp. 147–158.

Fuller, D.Q., Harvey, E., Qin, L., 2007. Presumed domestication? Evidence for wild rice cultivation and domestication in the fifth millennium BC of the Lower Yangtze region. Antiquity 81, 316–331.

Fuller, D.Q., Qin, L., 2009. Water management and labour in the origins and dispersal of Asian rice. World Archaeology 41 (1), 88–111.

Fuller, D.Q., Qin, L., Zheng, Y., Zhao, Z., Chen, X., Hosoya, L., Sun, G.-P., 2009. The domestication process and domestication rate in rice: spikelet bases from the Lower Yangtze. Science 323, 1607–1610.

Fuller, D.Q., Sato, Y., Castillo, C., et al., 2010. Consilience of genetics and archaeobotany in the entangled history of rice. Archaeological and Anthropological Sciences 2, 115–131.

Harris, D.R., 2007. Agriculture, cultivation and domestication: exploring the conceptual framework of early food production. In: Denham, T., Iriarte, J., Vrydaghs, L. (Eds.), Rethinking Agriculture: Archaeological and Ethnoarchaeological Perspectives. Left Coast, Walnut Creek, CA, pp. 16–35.

Henan Provincial Institute of Cultural Relics and Archaeology, 1999. Wuyang Jiahu (II) (in Chinese). Science Press, Beijing.

Hu, Y., Wang, S., Luan, F., Wang, C., Richards, M.P., 2008. Stable isotope analysis of humans from Xiaojingshan site: implications for understanding the origin of millet agriculture in China. Journal of Archaeological Science 35, 2960–2965.

Hygiene Section of the Rear Service Department of Shenyang Troops, 1970. Manual of Chinese Herbal Medicine Common in Northeast China (in Chinese). Liaoning Provincial Xinhua Bookstore, Shenyagn.

Jin, G.Y., Wang, C.M., Yan, S.D., Liu, C.J., Lan, Y.F., Tong, P.H., 2011. Study on the charred plant remains from Zhaojiazhuang, Jiaozhou, Shandong Province (in Chinese). In: Center for Scientific Archaeology of CASS (Ed.), Scientific Archaeology (3). Science Press, Beijing, pp. 37–53.

Kong, Q., 1996. Animal remains from the Xiaojingshan site (in Chinese, with Latin names). Huaxia Archaeology (Huaxia Kaogu) (2), 23–24.

Liu, C.J., Jin, G.Y., Kong, Z.C., 2008. Archaeobotany: Research on Seeds and Fruits (in Chinese). Science Press, Beijing.

Liu, L., Lee, G.-A., Jiang, L., Zhang, J., 2007. Evidence for the early beginning (c. 9000 cal. BP) of rice domestication in China: a response. The Holocene 17, 1059–1068.

Lu, H., Zhang, J., Wu, N., Liu, K., Xu, D., Li, Q., 2009. Phytoliths analysis for the discrimination of foxtail millet (*Setaria italica*) and common millet (*Panicum miliaceum*). PLoS ONE 4 (2), e4448. http://dx.doi.org/10.1371/journal.pone.0004448.

Luan, F.S., 2009. Houli Culture. In: Wagner, Mayke (Ed.), Chinese Archaeology and Palaeoenvironment I – Prehistory at the Lower Reaches of the Yellow River: The Haidai Region, Verlag Philip von Zabern·Mainz, pp. 1–16.

Pang, H.H., Chen, C.B., 2002. Wild Rice in China (in Chinese). Guangxi Provincial Science and Technology Press, pp. 5–7.

Pearsall, D.M., 1989. Phytolith analysis: laboratory analysis. In: Pearsall, D.M. (Ed.), Palaeothnobotany: a Handbook of Procedures. Academic Press, San Diego, New York, Boston, London, Sydney, Tokyo, Toronto, pp. 356–403.

Shandong Provincial Economic Plants editing committee, 1978. Shandong Provincial Economic Plants (in Chinese). Shandong People's Press, Jinan.

Shandong Provincial Institute of Cultural Relics and Archaeology, 1993. Preliminary report on the investigation of the Kiln site, Longsancun, Zhangqiu, Shandong Province (in Chinese). Huaxia Archaeology (Huaxia Kaogu) (1), 1–10.

Shandong Provincial Institute of Cultural Relics and Archaeology, 2000. The excavation of the Neolithic Xihe site of Zhangqiu, Shandong in 1997 (in Chinese). Archaeology (Kaogu) 10, 15–28.

Shandong Provincial Local History compiling committee, 1996. Shandong Provincial Record Natural Geography (in Chinese). Shandong People's Press, Jinan.

Song, Y.B., 2012. Zooarchaeology Research of Neolithic Period, Haidai Region (in Chinese). Ph. D. dissertation of Shandong University, Jinan, pp. 9–10.

Wang, C.M., Zhao, X.P., Jin, G.Y., 2010. Analysis on the flotation results from Liuzhuang, Hebi, Henan Province (in Chinese). Huaxia Archaeology (Huaxia Kaogu) (3), 90–99.

Wang, Y.B., Wang, S.G., Li, Z.G., 1993. New tasks for the prehistoric archaeology in the Haidai Region – dealing with Houli Culture (in Chinese). In: Zhang, X.H. (Ed.), Collected Papers of the International Congress for the 60th Anniversary of the Excavation of Chengziya (Chengziya yizhi faju 60 zhounian xueshu wenji). Qilu Publishing House, pp. 283–292.

Wang, Z.B., Zhang, K.S., Zhang, Z.X., Sun, T., Zhang, Z.G., 2012. The excavation report of the Xihe site of Zhangqiu, Shandong in 2008 (in Chinese). In: Shandong Provincial Institute of Cultural Relics and Archaeology (Ed.), Haidai Kaogu (Haidai Archaeology) 5. Science Press, pp. 67–138.

You, X., 1987. The wild rice in Chinese ancient records (in Chinese). Gujin Nongye (Ancient and Modern Agriculture) (1), 1–6.

Zhang, J., Lu, H., Wu, N., Yang, X., Diao, X., 2011. Phytolith analysis for differentiating between foxtail millet (*Setaria italica*) and green foxtail (*Setaria viridis*). PLoS ONE 6 (5), e19726. http://dx.doi.org/10.1371/journal.pone.0019726.

Zhang, C., 2011. On the remains of the first stage of Jiahu Culture (in Chinese). Cultural Relics (Wenwu) (3), 46–53.

Zhao, Z., Benfer Jr., R., Peperno, D., 1998. Distinguishing rice (*Oryza sativa* Poaceae) from wild *Oryza* species through phytolith analysis. Economic Botany 52, 134–145.

Zhao, Z., 2011. New archaeobotanic data for the study of the origins of agriculture in China. Current Anthropology 52 (Suppl. 4), S295–S306.

Zhejiang Provincial Institute of Cultural Relics and Archaeology, 2004. Archaeological Report of Puyang River Valley I – Kuahuiao. Cultural Relics Publishing House, Beijing.